

TU3B-04

Compact Low-loss Planar Magic-T Using Microstrip-slotline Transitions

Kongpop U-yen, Edward J. Wollack, Samuel H.
Moseley, John Papapolymerou and
Joy Laskar



¹NASA Goddard Space Flight Center
Microwave Instrument Technology Branch
Code 555, Greenbelt Rd.
Greenbelt, MD, 20771

²Georgia Electronic Design Center,
Georgia Institute of Technology

1

Outline

- Motivation
- Proposed Magic-T Design
 - Broadband Design Techniques
 - Microstrip-slotline Transition
 - Radiation Loss Reduction Techniques
- Hardware and Experimental Results
- Conclusion


2

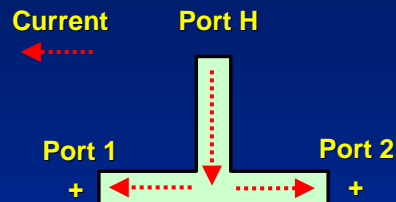
Motivation


- A practical magic-T should have high sum-to-difference port isolation, low phase and amplitude imbalance, as well as low ohmic and insertion loss.
- The structure should be compact, reliable and require the minimal number of fabrication steps to reduce complexity and cost.
- Slotline elements can be incorporated in the magic-T design to realize a broadband response. However, if not carefully designed, they may result in high insertion loss due to radiation.

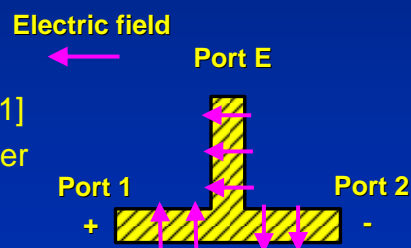
3

Microstrip line and slotline complementary properties

- Microstrip line 
 - Quasi-TEM mode
 - Broadband in-phase power combiner/divider
 - Low radiation loss, typically

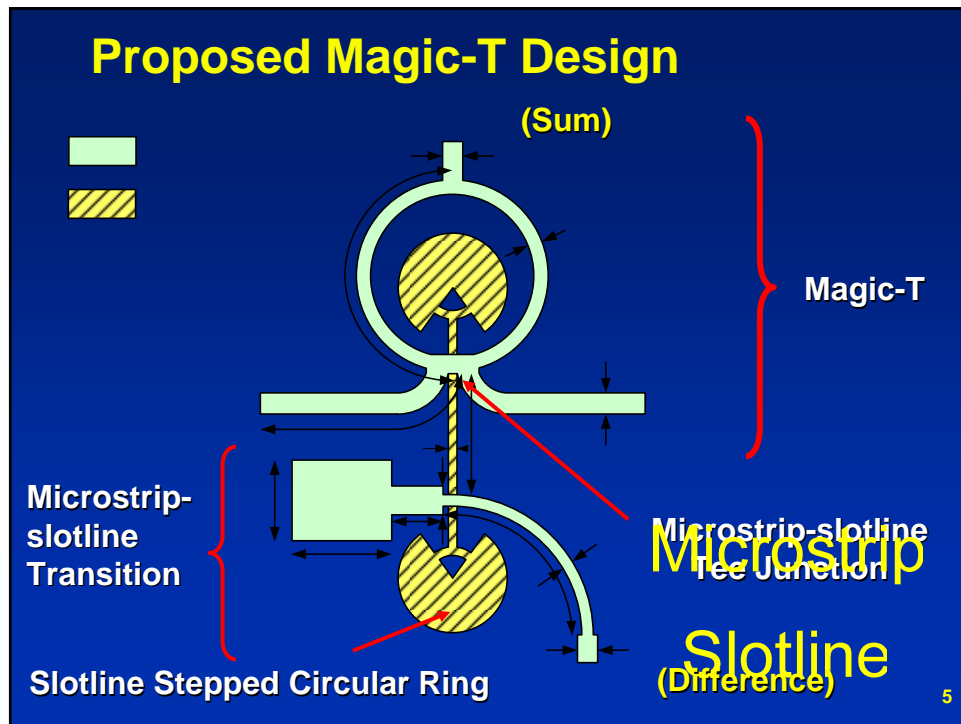


- Slotline 
 - Non TEM and almost transverse electric in nature [1]
 - Broadband out-of-phase power combiner/divider
 - May have high radiation loss



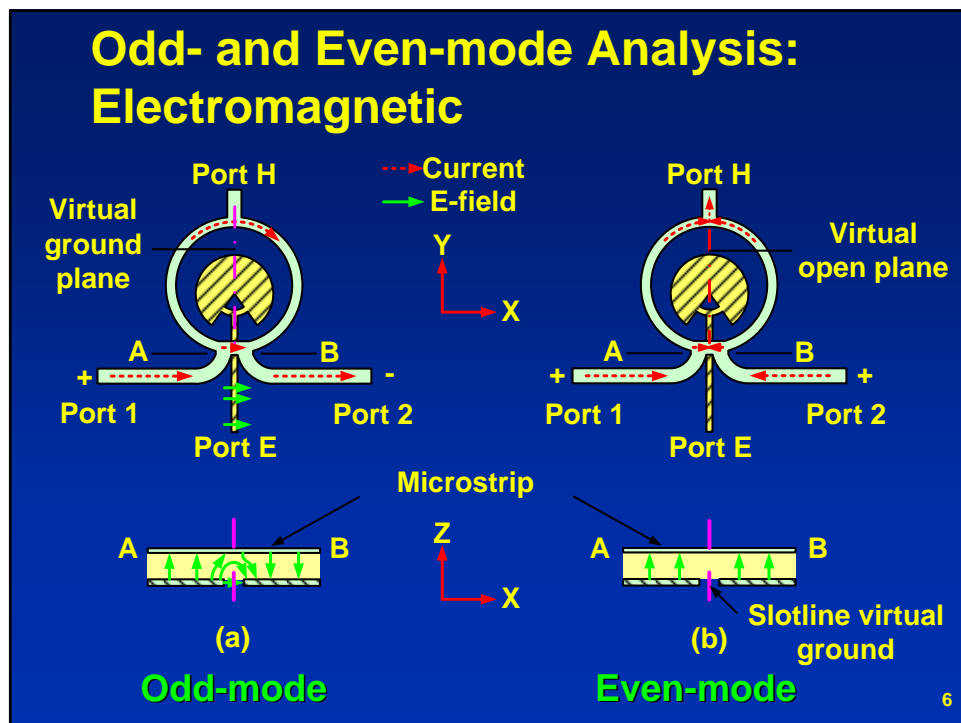
[1] K. C. Gupta, R. Garg, I. Bahl, P. Bhartia, "Microstrip lines and Slotlines," 2nd edition, Artech House, MA, 1996.

4



Port H

L_2

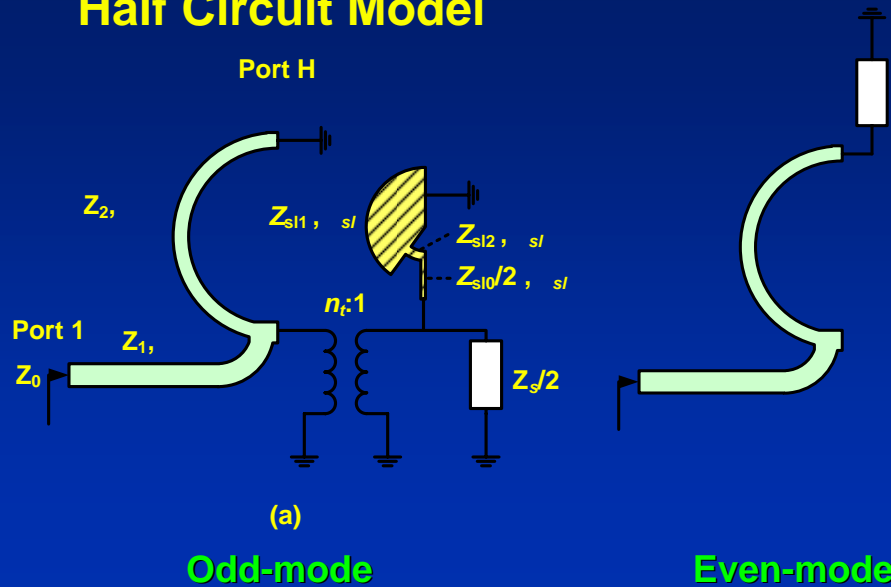


L_1

W_s
 W_{t1}
 L_{t1}

L_{t2}

Odd- and Even-mode Analysis: Half Circuit Model

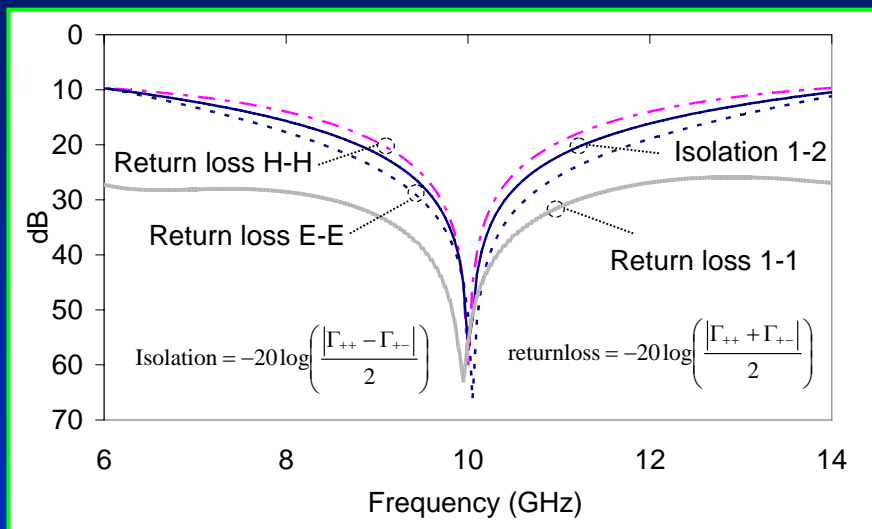


7

$\lambda/4$

θ_1

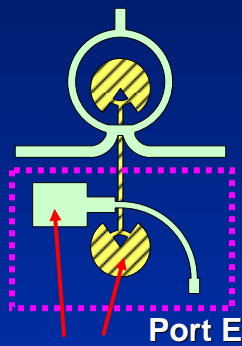
Modeled Frequency Responses



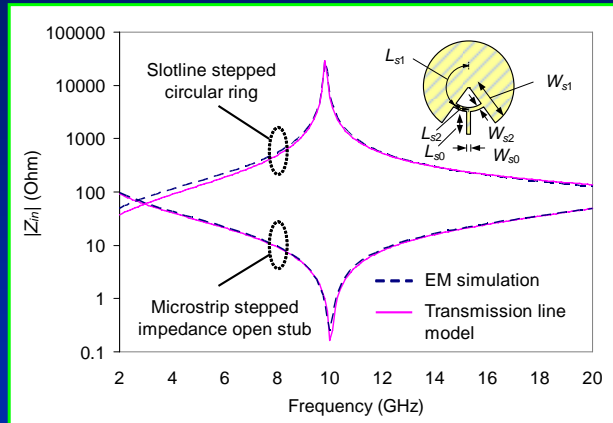
8

Microstrip-slotline Transition

Used for converting slotline to microstrip at port E [2]...



**Stepped
impedance
structure**



The frequency responses of the stepped impedance structures in the proposed magic-T.

[2] J. B. Knorr, "Slotline transitions," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-22, pp. 548-554, 1974.

9

Radiation Loss Reduction Techniques

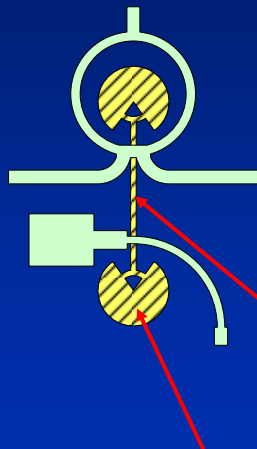
Magic-T Losses

1. Microstrip loss

- **Conductor Loss** $\sim \text{length}$
- **Dielectric Loss** $\sim \text{length/width}$
- **Radiation Loss** $\sim (\text{dielectric thickness}/\lambda)^2$

2. Slotline Loss

- **Radiation Loss** $\sim \text{Area}_{\text{effective}}/\lambda^2$



Slotline Connection

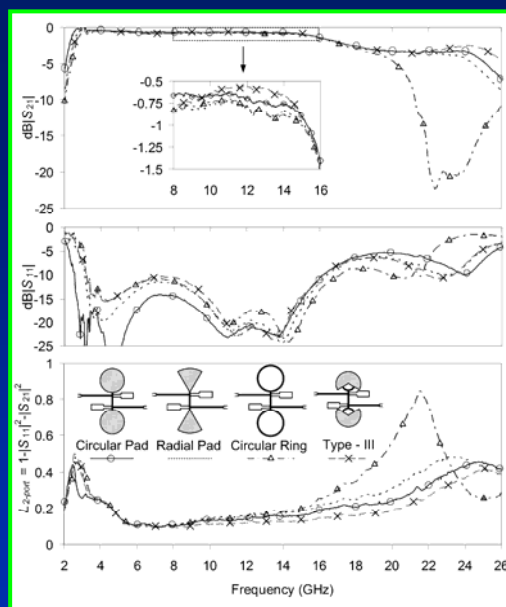
Slotline Terminations

10

Slotline Radiation Reduction Techniques

- Minimize slotline line length
- Use minimum slotline width and appropriate dielectric thickness
- Use slotline stepped circular ring terminations

[3] K. U-yen et. al. "Slotline stepped circular rings for low-loss microstrip-to-slotline transitions," *IEEE Microwave Wireless Comp. Lett.*, 2007, IEEE Microwave Wireless Components Letters, Vol. 17, No. 2, pp. 100-102.



Slotline termination test using Microstrip-slotline transitions on the 5-mil thick Roger's LCP substrate

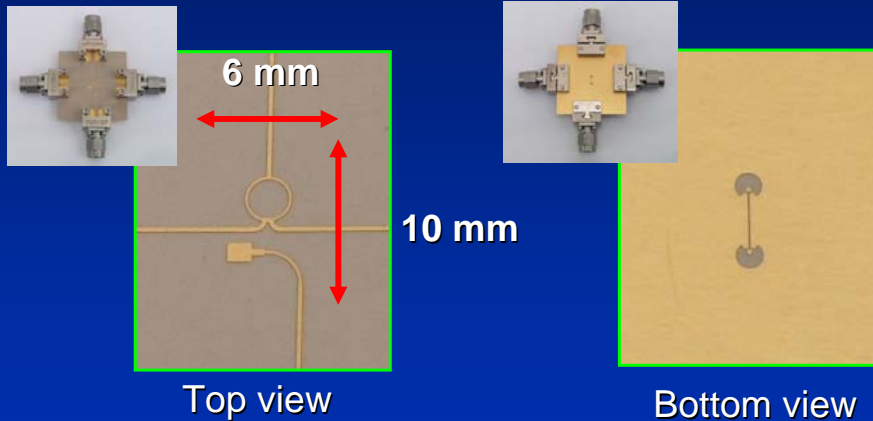
11

Slotline Stepped Circular Ring

- Reduces the effective electrical length of the slotline terminations.
- Shifts maximum radiation frequency away from the operating band.
- Provides the lowest radiation loss relative to other slotline terminations investigated.

12

Hardware and Experimental Results:

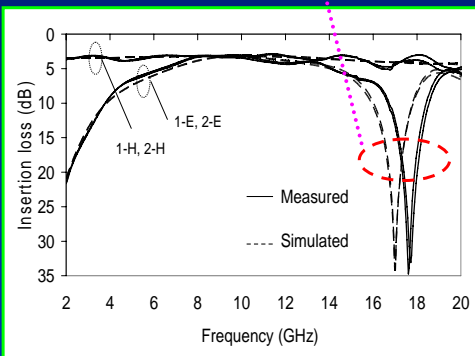


Photograph of the fabricated magic-T on 10 mil-thick Roger's Duroid 6010 substrate

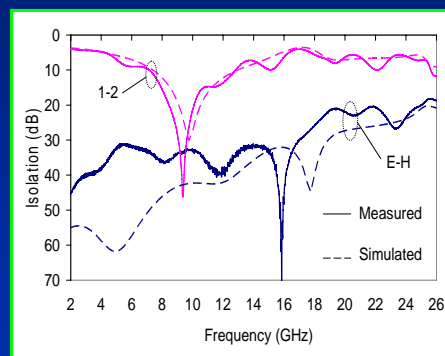
13

Hardware and Experimental Results: Insertion Loss & Isolation

Response mainly limited by
microstrip-slotline transition...



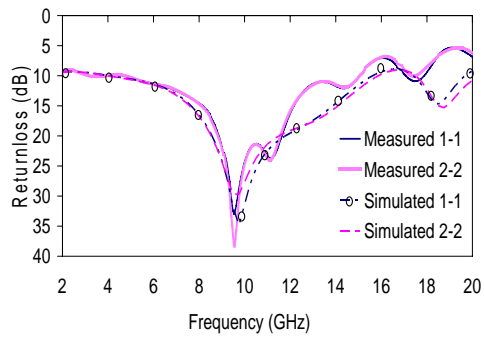
Measured Insertion Loss



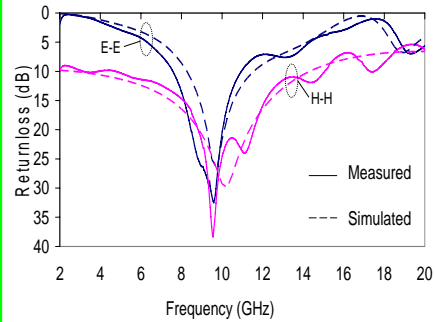
Isolation 1-2, E-H

14

Hardware and Experimental Results: Return Loss



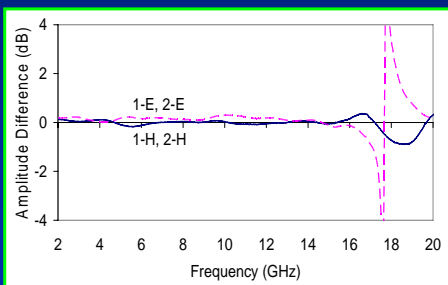
Return Loss 1-1, 2-2



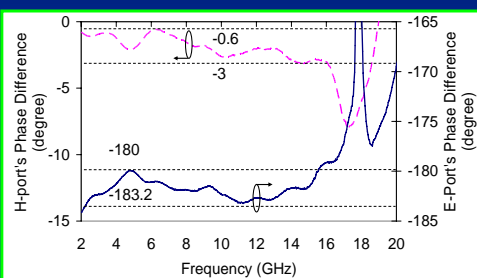
Return Loss E-E, H-H

15

Hardware and Experimental Results: Phase and Amplitude Imbalance



Phase Imbalance



Amplitude Imbalance

16

Pros & Cons

Pros

- Compact Geometry
- Simple to design and fabrication
 - Does not require air bridges or vias
- Low in-band insertion loss
- Broadband in-phase combiner
- Low phase and amplitude imbalance

Cons

- Narrowband out-of-phase response
- Narrowband port 1-2 isolation

17

Conclusion

- New compact planar magic-T was proposed
- The magic-T has low in-band insertion loss
- The magic-T has very low phase and amplitude imbalance
- The magic-T is simple to design and fabricate
- Currently investigating means of improving design's bandwidth

18



Thank you !



19

TABLE I
The magic-T circuit design parameters at 10 GHz

Microstrip line section	Slotline section
$Z_1=42.7 \Omega$, $Z_2=60.33 \Omega$, $Z_{t1}=40 \Omega$, $\theta_{t1}=23.3^\circ$, $\theta_{t2}=46.6^\circ$, $Z_{t2}=20 \Omega$	$Z_s=72.8 \Omega$, $Z_{s0}=72.8 \Omega$, $Z_{s12}=72.8 \Omega$, $\theta_{s10}=13.57^\circ$, $\theta_{s12}=6.2^\circ$, $Z_{s11}=163.4 \Omega$, $\theta_{s11}=34.95^\circ$, $\theta_s=113.3^\circ$

TABLE II
The physical parameters of the compact magic-T in millimeters

Microstrip line section	Slotline section
$L_1=2.62$, $W_1=0.26$, $L_2=1.83$, $W_2=0.14$, $L_t=2.80$, $W_t=0.16$, $L_{t1}=0.68$, $W_{t1}=0.37$, $L_{t2}=1.30$, $W_{t2}=1.05$	$L_s=1.92$, $W_s=0.10$, $L_{s0}=0.58$, $W_{s0}=0.10$, $L_{s1}=0.23$, $W_{s1}=0.1$, $L_{s2}=0.91$, $W_{s2}=0.71$

20